International Journal of ADVANCED RESEARCH & INNOVATIONS

Volume 13, Issue-12
December, 2023, P10
ISSN: 2319-9253

THE FUTURE OF PRECISION ONCOLOGY: CONVERGING FOUNDATION MODELS, AGENTIC AI, DIGITAL TWINS, AND MULTIMODAL CLINICAL INTELLIGENCE

[#1]**Dr. Anusha Pillai,** Professor, Department of Medical Oncology,
Dr. B. R. Ambedkar Medical College, Bengaluru, India
Anushapillai81@gmail.com

Abstract: Precision oncology is entering a transformative era driven by the convergence of foundation artificial intelligence (AI) models, agentic AI, digital twins, multimodal clinical intelligence, and continuously learning healthcare ecosystems. Traditional precision oncology has significantly improved diagnosis and treatment by incorporating molecular profiling and targeted therapies; however, fragmented biomedical data, limited interoperability, delayed clinical decision-making, and insufficient integration of heterogeneous patient information continue to constrain personalized cancer care. Recent advances in foundation AI models, multimodal transformer architectures, graph neural networks, self-supervised learning, reinforcement learning, and generative artificial intelligence have enabled comprehensive integration of radiological imaging, digital pathology, genomics, transcriptomics, proteomics, metabolomics, epigenomics, spatial biology, laboratory biomarkers, circulating tumor DNA, wearable physiological monitoring, electronic health records, biomedical literature, digital biomarkers, and longitudinal clinical outcomes into unified computational representations of cancer biology. Agentic AI systems extend these capabilities by autonomously coordinating diagnostic workflows, synthesizing biomedical evidence, optimizing therapeutic recommendations, monitoring disease progression, and supporting multidisciplinary clinical decision-making under human supervision. Simultaneously, digital twin technology enables continuously evolving virtual representations of individual patients capable of simulating disease progression, therapeutic response, toxicity, recurrence, and personalized treatment strategies. Emerging technologies including multimodal large language models, federated learning, retrieval-augmented generation, explainable artificial intelligence, cloud-native healthcare platforms, quantum computing, robotics, and digital health ecosystems further strengthen computational oncology by enabling collaborative, transparent, privacy-preserving, and adaptive clinical intelligence. Despite remarkable technological progress, important scientific, technical, ethical, and regulatory challenges remain regarding multimodal data harmonization, computational scalability, interoperability, cybersecurity, clinical validation, regulatory acceptance, and equitable implementation. This review provides a comprehensive overview of the future of precision oncology, emphasizing the convergence of foundation models, agentic AI, digital twins, and multimodal clinical intelligence as transformative technologies for next-generation cancer medicine.[1]

Keywords: *Precision oncology, Foundation models, Agentic AI, Digital twins, Multimodal clinical intelligence, Artificial intelligence, Computational oncology, Personalized therapeutics, Digital health, Precision medicine.*

1. Introduction

Cancer remains one of the most biologically complex diseases in medicine, characterized by continuous genomic evolution, epigenetic remodeling, immune adaptation, metabolic reprogramming, angiogenesis, stromal remodeling, and dynamic interactions among malignant cells, immune populations, vascular structures, and host physiology. These interconnected biological processes evolve throughout diagnosis, treatment, recurrence, metastasis, and survivorship, requiring precision oncology systems capable of integrating heterogeneous biomedical information across multiple biological scales.[2]

Volume 13, Issue-12
December, 2023, P10
ISSN: 2319-9253

Modern oncology generates enormous quantities of biomedical information through radiological imaging, digital pathology, genomic sequencing, transcriptomics, proteomics, metabolomics, epigenomics, spatial biology, laboratory investigations, circulating tumor DNA, wearable physiological monitoring, physician documentation, electronic health records, biomedical literature, and patient-reported outcomes. Although each modality contributes valuable biological insight, isolated interpretation frequently limits comprehensive characterization of evolving cancer biology and individualized therapeutic decision-making.[3]

The convergence of foundation AI models, agentic AI, digital twins, and multimodal clinical intelligence establishes a transformative computational framework capable of continuously integrating biomedical knowledge, supporting adaptive clinical reasoning, and enabling personalized precision oncology throughout the cancer care continuum.

2. Evolution Toward Intelligent Precision Oncology

Precision oncology has evolved from conventional histopathological classification toward increasingly comprehensive molecular characterization and computational intelligence. Early precision medicine primarily relied upon individual genomic alterations and targeted therapies, while subsequent advances incorporated radiological imaging, digital pathology, immunotherapy biomarkers, and multi-omics technologies into clinical practice.[4]

Deep learning substantially expanded computational capabilities by enabling automated feature learning from imaging, pathology, genomics, and electronic health records. Transformer architectures subsequently revolutionized biomedical artificial intelligence through contextual learning across heterogeneous biomedical modalities.

Foundation AI models now acquire transferable biomedical knowledge through large-scale self-supervised pretraining, enabling generalized reasoning across diagnosis, prognosis, biomarker discovery, therapeutic optimization, disease monitoring, clinical research, and translational oncology. Agentic AI and digital twins further extend these capabilities by introducing autonomous workflow coordination and predictive patient simulation.[5]

3. Foundation Models as the Core of Future Oncology

Foundation AI models differ fundamentally from conventional predictive algorithms because they acquire generalized biomedical representations from massive multimodal datasets before specialization for individual oncology applications. Rather than learning isolated prediction tasks, these models develop transferable computational knowledge applicable across diagnosis, prognosis, biomarker discovery, therapeutic optimization, disease monitoring, clinical trial design, and intelligent decision support.[6]

Self-supervised learning enables discovery of latent biological relationships without requiring extensive manual annotation, while multimodal transformer architectures align radiological imaging, digital pathology, genomics, transcriptomics, proteomics, metabolomics, epigenomics, laboratory biomarkers, wearable physiological monitoring, physician documentation, patient-reported outcomes, biomedical literature, and longitudinal clinical trajectories within unified computational embedding spaces.

Graph neural networks further characterize interactions among genes, proteins, signaling pathways, immune populations, imaging phenotypes, tissue architecture, therapeutic targets, physiological variables, environmental exposures, and clinical outcomes, thereby enabling systems-level computational reasoning across precision oncology.[7]

4. Computational Architecture of Multimodal Clinical Intelligence

Future oncology platforms will consist of interconnected computational layers responsible for biomedical data acquisition, preprocessing, multimodal representation learning, adaptive inference, agentic reasoning, digital twin simulation, predictive analytics, knowledge integration, and intelligent clinical decision support.[8]

Paper Available at: www.ijarai.com
DOI : https://doi.org/10.65713/ijaraiv13i1210

The acquisition layer continuously integrates radiological imaging, digital pathology, genomic sequencing, transcriptomics, proteomics, metabolomics, epigenomics, spatial biology, laboratory investigations, circulating tumor DNA, wearable physiological monitoring, medication history, physician documentation, patient-reported outcomes, biomedical literature, and electronic health records. Advanced preprocessing pipelines normalize imaging studies, harmonize molecular datasets, encode clinical narratives using natural language processing, synchronize temporal patient information, and continuously incorporate evolving biomedical evidence.

Foundation AI models subsequently generate generalized multimodal embeddings representing molecular biology, tissue architecture, imaging phenotypes, physiological function, environmental exposures, and longitudinal clinical trajectories while enabling downstream reasoning by agentic AI systems and digital twins.[9]

5. Agentic Artificial Intelligence in Precision Oncology

Agentic AI represents the next evolutionary stage of biomedical artificial intelligence by enabling intelligent systems capable of autonomous planning, reasoning, coordination, and adaptive execution under clinician supervision. Rather than performing isolated prediction tasks, agentic AI orchestrates complex clinical workflows by coordinating diagnostic evaluation, biomarker interpretation, evidence synthesis, therapeutic planning, multidisciplinary communication, and longitudinal patient monitoring.[10]

Agentic systems integrate radiological imaging, digital pathology, molecular diagnostics, laboratory biomarkers, wearable physiological monitoring, physician documentation, biomedical literature, clinical guidelines, and patient-specific information into comprehensive reasoning pipelines capable of generating adaptive recommendations. Large multimodal language models further facilitate communication between computational systems and healthcare professionals through natural-language interaction.

These capabilities substantially improve workflow efficiency, multidisciplinary collaboration, and personalized oncology while preserving meaningful human oversight.[11]

6. Digital Twins and Virtual Patient Modeling

Digital twin technology enables continuously evolving virtual representations of individual cancer patients synchronized with their biological counterparts through comprehensive integration of molecular biology, imaging, physiology, clinical history, environmental exposures, and therapeutic response. Foundation AI models continuously update digital twins using radiological imaging, digital pathology, genomics, transcriptomics, proteomics, metabolomics, laboratory biomarkers, circulating tumor DNA, wearable physiological monitoring, and longitudinal clinical outcomes.[12]

These adaptive computational patient models simulate disease progression, therapeutic responsiveness, toxicity profiles, recurrence risk, metastatic dissemination, and survival while enabling evaluation of multiple therapeutic strategies before implementation. Digital twins therefore provide clinicians with powerful computational tools supporting individualized therapeutic optimization and precision medicine.

Integration of digital twins with agentic AI further enables autonomous adaptation of treatment strategies according to continuously evolving patient biology.[13]

7. Multimodal Clinical Intelligence

Comprehensive precision oncology depends upon seamless integration of complementary biomedical modalities into unified patient-specific computational representations. Radiological imaging provides anatomical and functional characterization of tumors, digital pathology reveals microscopic tissue architecture, and multi-omics technologies—including genomics, transcriptomics, proteomics, metabolomics, epigenomics, immunomics, microbiomics, single-cell sequencing, and spatial biology—provide comprehensive molecular characterization of evolving cancer biology.[14]

Artificial intelligence harmonizes these diverse biomedical modalities using multimodal transformers, graph neural networks, biological knowledge graphs, and cross-modal attention mechanisms capable of generating adaptive

Paper Available at: ***www.ijarai.com***
DOI : https://doi.org/10.65713/ijaraiv13i1210

computational embeddings representing continuously evolving patient biology.

These multimodal representations substantially improve diagnosis, prognostic prediction, biomarker discovery, therapeutic optimization, adaptive disease monitoring, and personalized oncology.[15]

8. Digital Health and Continuous Intelligence

Digital health technologies including wearable biosensors, mobile health applications, remote physiological monitoring, smart medical devices, patient-reported outcomes, and Internet of Medical Things (IoMT) platforms continuously generate longitudinal physiological information throughout the cancer care continuum. These technologies extend precision oncology beyond hospitals by enabling continuous assessment of treatment response, toxicity, medication adherence, functional status, cardiovascular physiology, metabolic health, sleep quality, physical activity, and quality of life.[16]

Foundation AI models integrate wearable physiological measurements with laboratory biomarkers, molecular biology, radiological imaging, digital pathology, and electronic health records using multimodal transformer architectures. Continuous digital monitoring substantially improves early toxicity detection, adaptive disease monitoring, survivorship management, supportive care optimization, and real-world evidence generation.

Digital health therefore represents an essential component of future intelligent oncology ecosystems.[17]

9. Adaptive Personalized Oncology Ecosystems

The convergence of foundation AI models, agentic AI, digital twins, multimodal clinical intelligence, digital health technologies, laboratory biomarkers, biomedical literature, and longitudinal clinical trajectories establishes adaptive personalized oncology ecosystems capable of continuously learning from evolving biomedical information. Rather than analyzing individual biomedical modalities independently, these intelligent systems generate holistic computational representations of patient biology while autonomously supporting diagnosis, biomarker discovery, therapeutic optimization, disease monitoring, recurrence prediction, survival estimation, multidisciplinary communication, and personalized clinical decision-making under human supervision. This convergence establishes the computational foundation for continuously adaptive, evidence-based, explainable, and patient-centered precision oncology throughout the entire cancer care continuum.[18][19][20]

10. Intelligent Digital Twins and Predictive Patient Simulation

Digital twin technology represents one of the most transformative components of future precision oncology by creating continuously evolving virtual representations of individual cancer patients synchronized with their biological counterparts. Foundation AI models integrate serial radiological imaging, digital pathology, genomics, transcriptomics, proteomics, metabolomics, epigenomics, spatial biology, laboratory biomarkers, circulating tumor DNA, wearable physiological monitoring, medication history, patient-reported outcomes, environmental exposures, and longitudinal clinical information into adaptive computational patient models capable of simulating disease progression, therapeutic response, treatment-related toxicity, recurrence, metastatic dissemination, and survival.[21]

Unlike conventional predictive models, intelligent digital twins continuously update their computational representations as new biomedical information becomes available. Integration of multimodal molecular biology with predictive simulation enables virtual patients to evaluate multiple therapeutic strategies before implementation, optimize treatment sequencing, anticipate mechanisms of therapeutic resistance, personalize supportive care, estimate long-term clinical outcomes, and support adaptive treatment planning according to evolving patient biology.

When combined with agentic AI, digital twins become active computational partners capable of continuously monitoring patient trajectories, identifying clinically meaningful deviations, recommending evidence-based interventions, and supporting multidisciplinary oncology teams with predictive intelligence throughout the cancer care continuum.

Paper Available at: *www.ijarai.com*
DOI : https://doi.org/10.65713/ijaraiv13i1210

11. Agentic Clinical Intelligence and Decision Support

Agentic AI provides the computational infrastructure for next-generation clinical decision-support systems capable of integrating heterogeneous biomedical information into comprehensive patient-centered recommendations while operating under continuous human supervision. Rather than independently interpreting radiological imaging, digital pathology, molecular diagnostics, laboratory investigations, wearable physiological monitoring, medication history, physician documentation, patient-reported outcomes, and evidence-based clinical guidelines, agentic systems coordinate multiple specialized computational modules into unified clinical reasoning workflows.[22]

Interactive clinical intelligence platforms generate individualized diagnostic summaries, molecular biomarker analyses, radiomic and pathomic interpretations, digital twin simulations, therapeutic recommendations, toxicity estimates, recurrence probabilities, disease progression forecasts, survival predictions, and longitudinal treatment response assessments while facilitating collaboration among oncologists, radiologists, pathologists, surgeons, radiation oncologists, molecular biologists, pharmacists, nurses, genetic counselors, biomedical engineers, computational scientists, and healthcare administrators.

Importantly, clinicians remain responsible for validating algorithmic recommendations, interpreting uncertainty, balancing competing therapeutic objectives, communicating with patients, and making final individualized clinical decisions. This collaborative framework preserves human accountability while maximizing computational intelligence.

12. Continuous Learning Oncology Ecosystems

A defining characteristic of future precision oncology ecosystems is the ability to continuously evolve as new biomedical information becomes available. Artificial intelligence incorporates serial imaging examinations, computational pathology, circulating tumor DNA, laboratory biomarkers, wearable physiological monitoring, medication adherence, patient-reported outcomes, biomedical literature, clinical guidelines, pharmacological evidence, and real-world clinical outcomes into adaptive computational frameworks capable of continuously refining predictive accuracy throughout each patient's clinical journey.[23]

Continual learning algorithms enable incremental refinement of computational knowledge without catastrophic forgetting, while reinforcement learning optimizes diagnostic reasoning, therapeutic recommendations, clinical workflow coordination, and supportive care through iterative evaluation of longitudinal treatment outcomes. Agentic AI further integrates clinician feedback, multidisciplinary tumor board recommendations, and evolving biomedical evidence into continuous model improvement.

This adaptive computational paradigm transforms oncology into a continuously learning healthcare ecosystem capable of rapidly incorporating scientific discoveries into routine clinical practice.

13. Federated Multimodal Intelligence Networks

Development of highly generalizable foundation AI models requires access to diverse biomedical datasets representing multiple healthcare systems, imaging platforms, pathology laboratories, molecular technologies, wearable ecosystems, treatment protocols, geographic regions, and patient populations. Federated learning enables collaborative development of multimodal foundation models while preserving patient privacy and institutional governance through decentralized computational training.[24]

Participating healthcare institutions independently train local models using radiological imaging, digital pathology, genomics, transcriptomics, proteomics, metabolomics, laboratory investigations, wearable monitoring, liquid biopsy, electronic health records, and longitudinal clinical records while securely exchanging encrypted model parameters rather than identifiable patient information. Federated agentic AI systems further coordinate distributed learning while maintaining institutional autonomy and regulatory compliance.

These collaborative computational ecosystems establish international oncology intelligence networks capable of accelerating scientific discovery, reducing algorithmic bias, improving external validity, promoting equitable precision medicine, and supporting global cancer research

Paper Available at: www.ijarai.com
DOI : https://doi.org/10.65713/ijaraiv13i1210

while maintaining responsible biomedical data stewardship.

14. Explainability, Validation, and Ethical Governance

Successful implementation of converged precision oncology systems requires transparent, interpretable, reproducible, and rigorously validated computational platforms capable of supporting clinician confidence, patient trust, and regulatory approval. Explainable artificial intelligence (XAI) enables clinicians to understand computational reasoning through attention visualization, saliency maps, SHAP (Shapley Additive Explanations), feature attribution analysis, uncertainty estimation, multimodal attention mapping, confidence calibration, and counterfactual explanations identifying the imaging, molecular, pathological, physiological, behavioral, and clinical variables responsible for predictive outputs.[25]

Clinical deployment additionally requires standardized multimodal datasets, interoperable computational infrastructure, prospective multicenter validation, external benchmarking, cybersecurity safeguards, continuous monitoring for algorithmic bias, transparent reporting standards, and compliance with evolving international regulatory frameworks governing AI-enabled healthcare technologies.

Responsible implementation further depends upon patient privacy, informed consent, transparency, accountability, fairness, equitable access, responsible data governance, continuous post-deployment surveillance, and multidisciplinary oversight to ensure trustworthy integration of foundation AI models, agentic AI, and digital twins into routine oncology practice.

15. Future Perspectives

Future precision oncology ecosystems will increasingly integrate multimodal foundation models, multimodal large language models, agentic artificial intelligence, graph neural networks, reinforcement learning, federated learning, digital twins, spatial multi-omics, single-cell sequencing, liquid biopsy, quantum computing, Internet of Medical Things (IoMT), robotics, autonomous laboratory platforms, cloud-native healthcare infrastructure, and advanced biomedical knowledge graphs into unified computational oncology platforms.[26]

These next-generation ecosystems will continuously integrate molecular biology, radiological imaging, digital pathology, laboratory medicine, wearable physiological monitoring, environmental exposures, electronic health records, biomedical literature, pharmacological databases, real-world clinical outcomes, and global scientific evidence while autonomously coordinating diagnostic workflows, supporting adaptive clinical trials, optimizing therapeutic strategies, generating personalized patient education, and continuously synthesizing emerging biomedical knowledge.

Future oncology will therefore evolve into an intelligent, interconnected, predictive, preventive, adaptive, and continuously learning healthcare ecosystem centered on personalized patient care.

16. Discussion

The convergence of foundation AI models, agentic AI, digital twins, and multimodal clinical intelligence represents one of the most significant paradigm shifts in the history of oncology. Rather than functioning as isolated computational tools, these technologies collectively establish integrated clinical intelligence ecosystems capable of continuously synthesizing molecular biology, radiological imaging, digital pathology, laboratory biomarkers, wearable technologies, environmental information, biomedical literature, and longitudinal clinical trajectories into unified patient-specific representations.[27]

Applications spanning computational pathology, radiogenomics, biomarker discovery, digital twins, precision immunotherapy, adaptive therapeutics, intelligent clinical trials, remote patient monitoring, federated collaboration, digital health, survivorship management, autonomous workflow coordination, and explainable clinical decision support demonstrate the extraordinary potential of converged computational intelligence to redefine future cancer care. Nevertheless, successful implementation requires continued advances in multimodal data harmonization, explainable artificial intelligence, interoperability, computational infrastructure, cybersecurity, regulatory science, ethical governance, clinician

DOI : https://doi.org/10.65713/ijaraiv13i1210

education, and sustained multidisciplinary collaboration.

As biomedical knowledge and healthcare data continue to expand exponentially, integrated clinical intelligence platforms are expected to become the foundational infrastructure supporting precision oncology worldwide.

17. Conclusion

The future of precision oncology will be defined by the convergence of foundation AI models, agentic AI, digital twins, multimodal clinical intelligence, radiological imaging, digital pathology, multi-omics, laboratory biomarkers, wearable technologies, electronic health records, and longitudinal clinical intelligence into unified computational ecosystems capable of supporting accurate diagnosis, biomarker discovery, prognostic prediction, therapeutic optimization, adaptive disease monitoring, and continuously personalized cancer care throughout the patient journey.[28]

Advances in transformer architectures, multimodal learning, graph neural networks, self-supervised learning, federated learning, reinforcement learning, multimodal large language models, explainable artificial intelligence, digital twins, agentic AI, and generative artificial intelligence are expected to further strengthen intelligent oncology ecosystems, enabling increasingly accurate molecular characterization, transparent clinical reasoning, adaptive therapeutics, continuous disease surveillance, and predictive precision medicine.[29]

Although important scientific, technical, ethical, regulatory, and implementation challenges remain, sustained collaboration among oncologists, radiologists, pathologists, molecular biologists, biomedical engineers, computer scientists, nurses, healthcare organizations, policymakers, industry partners, patients, and regulatory agencies will accelerate the responsible implementation of these converging technologies. Their integration has the potential to improve patient outcomes, enhance healthcare efficiency, reduce disparities in cancer care, accelerate translational research, and establish a new era of intelligent, adaptive, trustworthy, and continuously learning precision oncology worldwide.[30]

References

1. Meric-Bernstam, F. et al. (2023) ‘Enhancing Precision Oncology Through Multimodal Data Integration’, Nature Reviews Clinical Oncology, 20(4), pp. 267-283.

2. Singhal K, Azizi S, Tu T, et al. Large language models encode clinical knowledge. Nature. 2023;620(7972):172–180. Doi:10.1038/s41586-023-06291-2.

3. Xu H, Usuyama N, Bagga J, et al. A whole-slide foundation model for digital pathology from real-world data. Nature. 2024;630(8015):181–188. Doi:10.1038/s41586-024-07441-w.

4. Moor M, Banerjee O, Abad ZSH, et al. Foundation models for generalist medical artificial intelligence. Nature. 2023;616(7956):259–265. Doi:10.1038/s41586-023-05881

5. Bommasani R, Hudson DA, Adeli E, et al. On the opportunities and risks of foundation models. arXiv. 2021. Doi:10.48550/arXiv.2108.07258.

6. Dr. Ohmini Krishnamurthy Rajendran (Author), AI-BASED RADIOGENOMIC MODELS FOR PREDICTING IMMUNOTHERAPY RESPONSE IN SOLID TUMORS, Vol. 51 No. 4 (2023): October-December 2023, Power System Protection and Control, ISSN-1674-3415, https://pspac.info/index.php/dlbh/article/view/321 , DOI: https://doi.org/10.46121/pspc.51.4.4

7. Dr. Latha Kiran Krishna Rajendran (Author), IMMUNOTHERAPY AND CELL THERAPY: DEVELOPING CAR-T CELL THERAPIES AND OTHER IMMUNE-BASED TREATMENTS FOR CANCER AND AUTOIMMUNE DISEASES, Vol. 51 No. 2 (2023): April-June 2023, Power System Protection and Control, ISSN-1674-3415, https://pspac.info/index.php/dlbh/article/view/304 , DOI: https://doi.org/10.46121/pspc.51.2.7

8. Chakraborty, S. et al. (2022) ‘Multi-omics Integration in Oncology: From Data to Clinical Insights’, Cancer Cell, 40(8), pp. 805-823.

9. Dr. Ohmini Krishnamurthy Rajendran (Author), FEDERATED RADIOLOGY AI MODELS FOR MULTI-INSTITUTIONAL CANCER DIAGNOSIS WITHOUT DATA SHARING, Vol. 51 No. 4 (2023): October-

December 2023, Power System Protection and Control, ISSN-1674-3415, https://pspac.info/index.php/dlbh/article/view/323, DOI: https://doi.org/10.46121/pspc.51.4.5

10. Dr. RajathaMaradiHemanth Kumar (Author), AI-Driven Liquid Biopsy Systems for Early Cancer Detection and Personalized Oncology, Vol. 51 No. 4 (2023): October–December 2023, Power System Protection and Control, ISSN: 1674-3415, https://pspac.info/index.php/dlbh/article/view/388, DOI: https://doi.org/10.46121/pspc.51.4.7

11. Joshi, A. et al. (2023) 'Multimodal Learning for Precision Oncology: Beyond Single-modality Analysis', npj Precision Oncology, 7(1), p. 28.

12. Huang, S.C. et al. (2020) 'Fusion of Medical Imaging and Electronic Health Records Using Deep Learning: A Systematic Review', npj Digital Medicine, 3(1), p. 136.

13. Dr. RajathaMaradiHemanth Kumar (Author), PAN-System Cancer Intelligence: Integrating Blood, Immune, Microbiome, and Tumor Microenvironment Data Using Foundation Models, Vol. 51 No. 4 (2023): October–December 2023, Power System Protection and Control, ISSN: 1674-3415, https://pspac.info/index.php/dlbh/article/view/389, DOI: https://doi.org/10.46121/pspc.51.4.8

14. Lambin, P. et al. (2017) 'Radiomics: Extracting More Information from Medical Images Using Advanced Feature Analysis', European Journal of Cancer, 48(4), pp. 441-446.

15. Zwanenburg, A. et al. (2023) 'The Image Biomarker Standardization Initiative: Standardized Quantitative Radiomics for High-Throughput Image-based Phenotyping', Radiology, 308(2), e221422.

16. Chen, R.J. et al. (2023) 'Towards a General-Purpose Foundation Model for Computational Pathology', Nature Medicine, 29(4), pp. 850-862.

17. Kather, J.N. et al. (2022) 'Pan-cancer Image-based Detection of Clinically Actionable Genetic Alterations', Nature Cancer, 3(7), pp. 789-799.

18. Chaudhary, K. et al. (2021) 'Deep Learning-Based Multi-Omics Integration Robustly Predicts Survival in Liver Cancer', Clinical Cancer Research, 27(5), pp. 1248-1259.

19. Cancer Genome Atlas Research Network (2013) 'The Cancer Genome Atlas Pan-Cancer Analysis Project', Nature Genetics, 45(10), pp. 1113-1120.

20. Huang, S.C. et al. (2021) 'Self-supervised Learning for Medical Image Classification: A Systematic Review', IEEE Transactions on Medical Imaging, 40(8), pp. 2021-2037.

21. Moor, M. et al. (2023) 'Foundation Models for Generalist Medical Artificial Intelligence', Nature, 616(7956), pp. 259-265.

22. Lambin, P. et al. (2017) 'Radiomics: Extracting More Information from Medical Images Using Advanced Feature Analysis', European Journal of Cancer, 48(4), pp. 441-446.

23. Zwanenburg, A. et al. (2023) 'The Image Biomarker Standardization Initiative: Standardized Quantitative Radiomics for High-Throughput Image-based Phenotyping', Radiology, 308(2), e221422.

24. Chen, R.J. et al. (2023) 'Towards a General-Purpose Foundation Model for Computational Pathology', Nature Medicine, 29(4), pp. 850-862.

25. Kather, J.N. et al. (2022) 'Pan-cancer Image-based Detection of Clinically Actionable Genetic Alterations', Nature Cancer, 3(7), pp. 789-799.

26. Chaudhary, K. et al. (2021) 'Deep Learning-Based Multi-Omics Integration Robustly Predicts Survival in Liver Cancer', Clinical Cancer Research, 27(5), pp. 1248-1259.

27. Cancer Genome Atlas Research Network (2013) 'The Cancer Genome Atlas Pan-Cancer Analysis Project', Nature Genetics, 45(10), pp. 1113-1120.

28. Huang, S.C. et al. (2021) 'Self-supervised Learning for Medical Image Classification: A Systematic Review', IEEE Transactions on Medical Imaging, 40(8), pp. 2021-2037.

29. Moor, M. et al. (2023) 'Foundation Models for Generalist Medical Artificial Intelligence', Nature, 616(7956), pp. 259-265.

30. Hanahan D. Hallmarks of cancer: new dimensions. Cancer Discov. 2022;12(1):31–46. Doi:10.1158/2159-8290.CD-21-1059.